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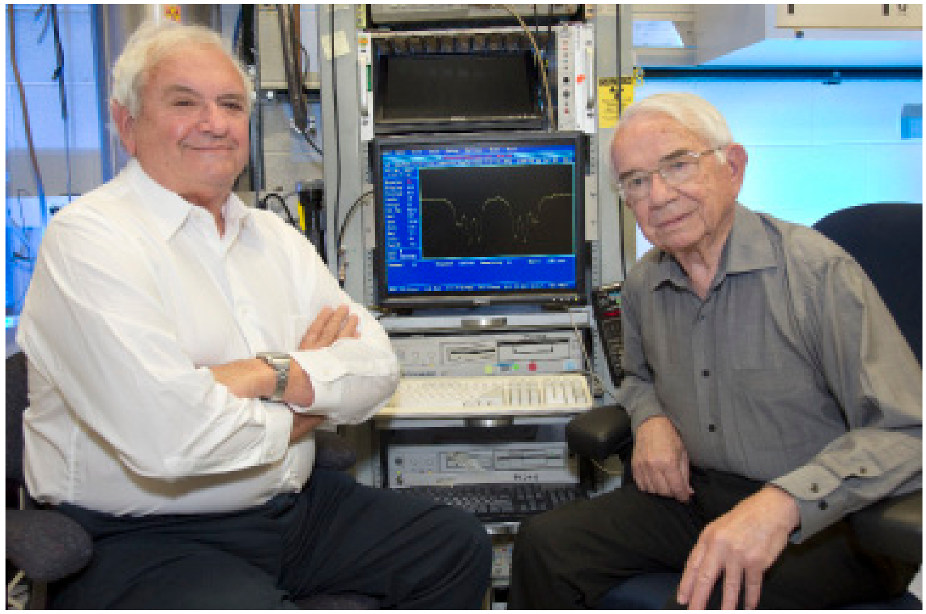
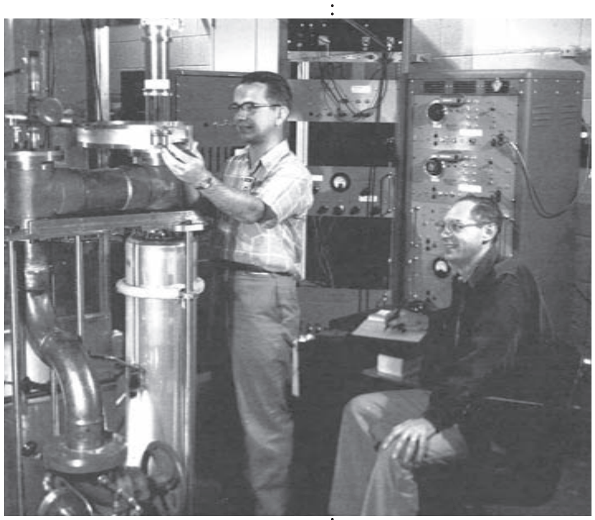
INSIDE



Long-time collaborators Moshe Pasternak (left) and R. Dean Taylor.

Photo by Sandra Valdez, IRM-CAS

Below, in a 1950s-era photo, R. Dean Taylor (left) and Prof. Greg Dash perform seminal studies of the normal fluid densities of liquid helium-3/ helium-4 mixtures. "The picture predated our work with the Mössbauer effect, but our work with liquid helium-3 was equally important. In fact, Greg and I were also collaborators on my first Mössbauer adventures," Taylor said.



R. Dean Taylor

Celebrating 60 years of materials science research

By Diana Del Mauro, ADEPS Communications

Although he retired 24 years ago, R. Dean Taylor remains a fixture in the Condensed Matter & Magnet Science group (MPA-CMMS). Believing deeply in a field he helped pioneer, he returned as a guest scientist because, he said, his work was "truly succeeding" and by pursuing his "hobby" he could continue to provide "meaningful research and services."

Taylor's specialty is the Mössbauer effect (ME), an exotic physics phenomenon allowing scientists to capture high-resolution measurements of a materials sample by exposing it to gamma rays. An obvious advocate of the spectroscopy technique, Taylor has stayed true to this highly specialized field far longer than the Nobel Prize-winning scientist who discovered it.

"I'm the only one at Los Alamos doing Mössbauer effect and probably have been since I retired, but when it was discovered in 1959 there were perhaps 20 people here from all walks of physics … trying to discuss, first of all, is this possible," he said.

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Los Alamos NATIONAL LABORATORY EST. 1943

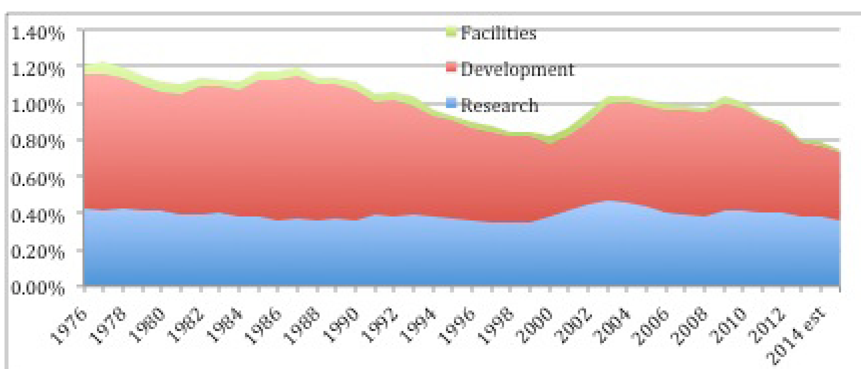
From David's desk . . .

I recently sent an e-mail to the Division announcing my intent to retire at the end of August. I started at the Lab in 1975—roughly half of the people in MPA Division were not born yet at that time. I've served under 8 of the 10 Laboratory Directors since the Lab was created. When I started, it was Los Alamos Scientific Laboratory, and we reported to the Atomic Energy Commission. I've seen a lot of changes at the Laboratory. As I said in my e-mail, LANL has been a good place to work, and I have had the privilege of working with dedicated and creative scientists throughout my career. This has been particularly true of MPA Division.

I believe MPA Division has good prospects for the future. Each of the groups has unique strengths and opportunities and core efforts that are doing well. The CINT program is robust and the science it is enabling will sustain LANL's leadership in materials science. The NHMFL has had tremendous success in establishing new milestones in high-magnetic-field generation, and combined with other activities in CMMS will continue LANL's leadership in condensed matter physics. The prospects for continued funding for the fuel cell program look good, and the use-inspired science it enables (along with other energy programs in MPA-11) will sustain LANL's leadership in key applied energy efforts. The credit for these successes must primarily be given to MPA's scientific staff.

"LANL has been a good place to work, and I have had the privilege of working with dedicated and creative scientists throughout my career. This has been particularly true of MPA Division."

Since this is my last "From the Desk" article, I wanted to leave you with a couple of thoughts about the future of the Laboratory and your future. One of my biggest concerns about the Laboratory and the nation is the declining funding available for research and development. The plot shows the trend in federal R&D funding as a percentage of gross domestic product. This fraction has declined by 1/3 over my career at LANL, mostly in the area of development and investment in new facilities. I believe it is important that we work to reverse this trend. You can make a difference by continuing to advance use-inspired science, but you must also create the narrative that helps the public understand the impact of the science. Being able to explain the impact of your work is a skill I encourage all of you to develop and exercise.



My second piece of advice comes from my personal perspective on what has characterized the people I have most enjoyed working with at LANL. Those people displayed an intellectual curiosity that was the main driver for the work they pursued, and they pursued their work with a high degree of personal integrity. Their intellectual curiosity contributed to a sense of excitement about their research and development, and their devotion to their work inspired others to follow their lead. Their personal integrity made them trustworthy. I was happiest in my work when I was surrounded by people exhibiting these characteristics. I suspect the future will bring many challenges to MPA and to you as individuals. As you face those challenges, face them with integrity and focus your intellectual efforts on exciting research and development.

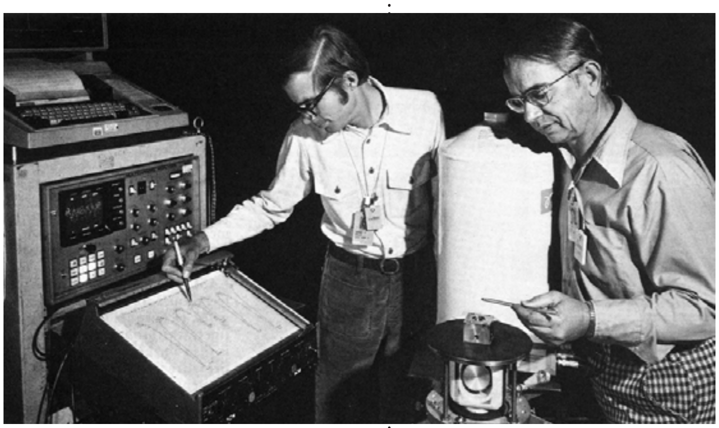
MPA Deputy Division Leader David Watkins

From Jeff's desk . . .

In this, my first "From the Desk," I would like to tell you a little about myself and then talk about MPA-11.

I came to the Lab as a postdoc a long time ago to work with Dean Taylor in what was then Q-10, Energy Division (this group subsequently became P-10, MST-10, and is now MPA-CMMS). I worked with Dean using the Mössbauer effect to study the properties of so-called re-entrant superconductors and also to probe the electronic property changes in iron metal as a function of pressure using diamond anvil cells, which were relatively new tools at the time. I subsequently joined CMB-5 (soon to become MST-5) initially working with James L. Smith, now of MST-6, former Lab employee Greg Stewart, Lab affiliate Zachary Fisk, and later, many others, including Joe Thompson of MPA-CMMS, on correlated electron—or often called at the time, heavy fermion—materials. When high temperature superconductors were discovered in 1988, I joined the newly founded Exploratory Research and Development Center, which was set up to perform R&D on these new materials and to develop a model for DOE labs to work with industry; this model eventually became the CRADA (Cooperative Research and Development Agreement), still in use today. The ERDC became MST-STC (Superconductivity Technology Center) in the early 1990s and then MPA-STC in 2006. My work there focused on determining and understanding the magnetic and transport critical current properties (i.e., the performance) of high temperature superconductors. In the early 1990s I went on change of station to Tokyo, where I worked at the Superconductivity Research Laboratory of the International Superconductivity Technology Center, a consortium of mostly Japanese companies. Much later, in 2007, I took a nine-month hiatus from the STC to help out CINT as an acting deputy group leader during its search for a permanent deputy. Back in the STC, I continued as team leader for our Los Alamos Research Park superconductor scale-up effort for several more years—until MPA-STC lost about 75% of its funding when DOE's applied superconductivity program was cancelled. In March 2012, most of the former STC was merged into MPA-MC (soon to become MPA-MSID and now MPA-11) with some staff joining MPA-CMMS because the technical "fit" was better there. From that point on I have served as acting deputy group leader for MPA-11. In August 2012 I took on the additional position of operational support for ADEPS, where I spend half of my time, much of that at TA-53 and LANSCE. I also took another acting position with CINT during its recent search for a permanent deputy, who is Kristin Omberg. This was a chance to work more closely with some of my colleagues of six years earlier. I have been back in MPA-11 now since December, working under Andrew Dattelbaum and with my fellow deputy, Brian Scott. So, as you can see, I have been a member of all of the extant groups in MPA Division.

"... I have been a member of all the extant groups in MPA Division."



This 1979 photo from *The Atom* shows Jeff Willis and R. Dean Taylor performing Mössbauer spectroscopy on iron.

My present office is in TA-3, SM-32 in the old STC office area; our lead admin, Julie Garcia, is also located there. The office area was recently refreshed from its ~30-year-old original state and now houses MPA-11 staff who moved from TA-48 to work in their new lab space in the Materials Science Laboratory infill area (rooms B220 & B230, second floor, east side). Many operations are up and running in this great new lab space—a construction project largely overseen by Andrew and Brian. I am the deputy responsible for MPA-11's footprint in the Materials Science Complex and at the Los Alamos Research Park. Oh yes, I am also the MPA Division Electrical Safety Officer and effectively the lead Pressure Safety Officer in MPA. My door is always open, so please stop by if you have an issue with which I can help or just to chat.

MPA-11 Deputy Group Leader Jeff Willis

Taylor cont.

Taylor now performs fundamental studies of iron and tin compounds, including measurements relevant to maintaining aging nuclear weapons. Unless he's on an extended vacation, he runs experiments almost every day.

"If you're having fun, you don't notice the clock," he said, on a day he was looking at "black gunk" thought to contain iron. He reveled in the fact that he can obtain the Mössbauer information without destroying the sample, a screening difficult to achieve with wet chemistries.

"Dean used the Mössbauer effect as an important diagnostic tool for areas of physics where it had never before been considered," said Laboratory Fellow Albert Migliori (National Security Education Center, NSEC), who began his career as Taylor's postdoctoral researcher. "He combined low-temperature physics and nuclear physics in a vital and engaging way to address topics in superconductivity, magnetism, energy, and more."

"He has used (ME) to solve important problems in a wide range of fields, from chemistry to solid-state physics and geophysics," added Hans Frauenfelder, a Theoretical Biology & Biophysics (T-6) guest scientist, and author of an early book on ME. "A deep knowledge of the underlying physics is necessary for this research, and Dean has it."

Mössbauer spectroscopy can answer many kinds of scientific questions and has practical applications in the steel industry and medicine, with ongoing research resulting in about 1,000 international papers annually. United States participation has fallen, as has research funding. The radioactive parent Mössbauer sources are no longer produced in the US, and only a few of the dozens of ME isotopes can now be purchased on the international market.

Yet, Taylor carries on. In a collaboration that began 10 years ago, Andrea Labouriau (Chemical Diagnostics & Engineering, C-CDE) and Taylor are investigating ways to reduce the amount of tin catalyst required to make foams for weapons. "Dean's work represents an important contribution to better understand aging mechanisms in room-temperature vulcanized (RTV) polysiloxane foams," she said.

Tin-119 is one of the best Mössbauer isotopes, and these studies nicely complement Labouriau's other measurements. "We're making progress in understanding how much tin is necessary and what the lifetimes of these foams are, in samples that might even be 20 years old," Taylor said.

John Gordon (Inorganic Isotope & Actinide Chemistry, C-IIAC) has tapped ME to examine physical properties of low-valent, iron-containing molecules. "We have a general

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Solving scientific problems the Mössbauer way

"When World War II ended, I said 'hoorah' with everyone else, and we soon learned not only about the bomb, but also we learned about Los Alamos," said Dean Taylor, whose brothers were soldiers. "I remarked to my father at the time that that is where I would like to work."

Having discovered the Lab's low-temperature physics group through his graduate studies professor, who spent summers here, Taylor, with a fresh PhD in physical chemistry, joined the Laboratory during the peak of hydrogen bomb testing. He performed liquid helium-3/helium-4 fundamental properties studies. He was a principal participant on a liquid D-T core thermonuclear shot at Eniwetok designed to produce new high Z elements.

When Rudolf Mössbauer, a German doctoral student, claimed to have observed nuclear resonance absorption of gamma rays at low temperatures using a simple apparatus that included a phonograph turntable, Los Alamos and Argonne national laboratories quickly ran separate experiments to test the findings. *Physical Review Letters* (*PRL*) published the new results in 1959, establishing ME as a remarkable technique for obtaining solid-state information from a nuclear physics probe. Taylor leapt into the new field, his low-temperature research at Rice making him a natural convert. Early on he was delighted to host Mössbauer for a dinner in his home during Mössbauer's visit to Los Alamos.

Between 1958 and 1967, when the field's research competition was fierce, Taylor was among the top 20 scientists in the world with the highest number of ME publications. He mainly reported on induced magnetic moments in dilute alloys and on brute force nuclear polarization in iron metal at 0.02 K. "In the early days, any equipment development or science result was a new discovery," he said. "Sometimes it was data today, analysis tomorrow, write paper, and submit to *PRL* the next day."

First beholden to nuclear physics, ME quickly spread to other fields, such as relativity and solid-state physics, the latter of which Taylor pursued. "Dean used Mössbauer spectroscopy as a probe of magnetic fields, instead of using magnetic fields as a probe of the Mössbauer nuclei," said Albert Migliori, director of Los Alamos's Seaborg Institute. "This led to some new understanding about how magnetism and superconductivity interact."

Taylor studied eight Mössbauer isotopes, but once the nation's nuclear reactors shut down the ability to prepare most of the Mössbauer sources was lost.

continued on next page

Taylor cont.

interest in nonprecious, earth-abundant metal containing catalysts, such as those that contain iron, as they are potentially useful in a variety of energy-related applications," he said.

Taylor's legacy, some say, transcends his Mössbauer accomplishments. "I think Dean's contribution to the Lab primarily has been the number of excellent postdocs that he has supervised and who have gone on to take leading roles at the Lab," said MPA-CMMS colleague Joe Thompson.

"While Dean started in the weapons program during the early testing of thermonuclear weapons in the South Pacific, he was one of the core people at the Lab who created a strong fundamental research program, to attract the best young scientists," said Martin Maley, his former postdoc, now a retired staffer. "He is one of the kindest people I have ever known. When you were a postdoc, you were part of his family. His real legacy is as a mentor."

"For me, he was a great mentor and an even greater colleague," retired scientist Dennis Erickson said. "He was and remains quietly driven, an attribute that resulted in sustained productivity, innovation, and discovery."

Mössbauer cont.

With Tel Aviv University professor Moshe Pasternak, who has been visiting Los Alamos every summer for the past 30 years, Taylor pioneered Mössbauer spectroscopy using diamond anvil pressure cells. The breakthrough was material studies at ever-higher pressures, enabling new insights into magnetic, electronic, and structural details. Besides basic research on iron compounds, they have provided support studies for Los Alamos scientists in the areas of catalysts, geology, and high pressure.

"In the early days, any equipment development or science result was a new discovery."
—R. Dean Taylor

"Iron compounds have been studied using all kinds of techniques because they have a wealth of different electronic states, not only multi-valence but multi-spin states, all with different characteristics. What Mössbauer does is follow those states as the pressure and temperature changes," Taylor said. "We've been able to prove and disprove some of the proposals that have been made for the state of iron in various conditions, and, I think, made a lot more solid story for iron."

Measuring the emergence of superconductivity

NHMFL magnetic fields make it possible

As part of an international collaboration, National High Magnetic Field Laboratory scientists used applied magnetic fields to measure the normal state out of which superconductivity emerges in the mysterious underdoped regime. *Nature* recently published the paper, the culmination of years of experimental work at Los Alamos.

Relevant to the field of high-transition-temperature (high-Tc) superconductivity, the authors report angle-resolved quantum oscillation measurements in the underdoped copper oxide $YBa_2Cu_3O_{6+x}$. These measurements reveal a normal ground state comprising electron-like Fermi surface pockets located at the nodes in the superconducting wave function. Furthermore, they point uniquely to an underlying bidirectional superlattice structure of long wavelength with features in common with the charge order identified recently by complementary x-ray scattering and spectroscopic techniques.

Superconductivity may therefore be viewed as emerging from the pairing of quasiparticles on Fermi pockets located in the nodal region of momentum space. Quantum oscillations of the normal ground state underpinning superconductivity in underdoped $YBa_2Cu_3O_{6+x}$. are measured at the National High Magnetic Field Laboratory (Los Alamos and Tallahassee, Florida sites) using the contactless resistivity technique. The strength of magnetic fields in which the measurements were carried out (up to 85 T and 100 T) is essential for both suppressing long-range superconducting order and enabling comprehensive angle-resolved measurements.

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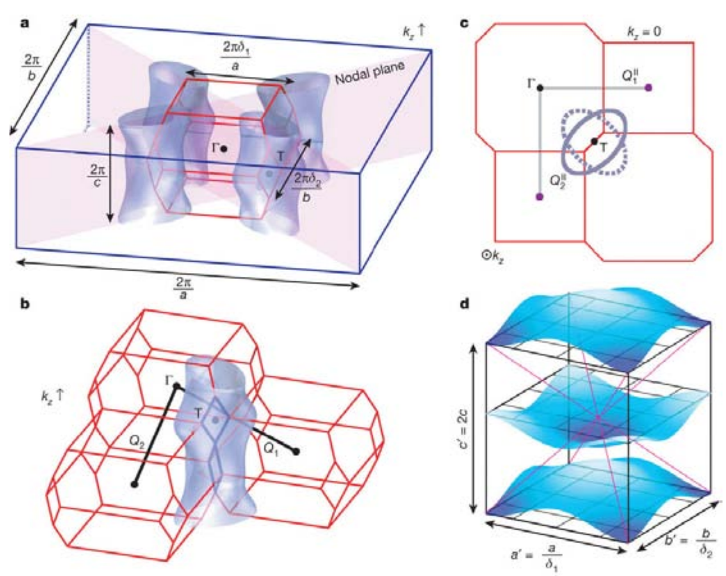

Fermi surface of $YBa_2Cu_3O_{6.56}$ inferred from quantum oscillation measurements.

Measuring cont.

The sample and the proximity detector oscillator coil to which it is coupled are rotated in situ through different polar (θ) and azimuthal (ϕ) angles before each magnetic field pulse extending to 65 T or 85 T. Quantum oscillation measurements for $\theta = 0$ are extended to 100 T. The sample temperature is maintained close to $T \approx 1.5$ K throughout the experiment by direct immersion in superfluid helium-4.

Quantum oscillation data can be used to identify characteristics of the momentum-space electronic structure in the way that, for example, x-ray data can be used to identify the real-space lattice structure of a crystal. For this study, the data was employed to identify the correct Fermi surface model.

This work was performed as part of the U.S. Department of Energy, Office of Science, BES-MSE “Science of 100 Tesla” program. The experimental work was performed at the National High Magnetic Field Laboratory, which is supported by NSF co-operative agreement number NSF-DMR 1157490, the state of Florida, and the DOE. Reference: “Normal-state nodal electronic structure in underdoped high-T_c copper oxides,” *Nature* (2014) doi:10.1038/nature13326. Los Alamos authors are Neil Harrison, Fedor Balakirev, and Moaz Altarawneh (Condensed Matter & Magnet Science, MPA-CMMS) with collaborators from Cambridge University, UK; Mu’tah University, Jordan; University of Warwick, UK; University of British Columbia, Canada; and Canadian Institute for Advanced Research. The work supports the Lab’s Global Energy mission and Materials of the Future science pillar.

Technical contact: Neil Harrison

Durakiewicz selected as program director for condensed matter physics at NSF

Tomasz Durakiewicz (Condensed Matter and Magnet Physics, MPA-CMMS) has recently been selected as program director for condensed matter physics at the National Science Foundation’s headquarters in Arlington, VA. During his two-year tenure he will manage the roughly \$50M/year program of condensed matter physics within the Division for Materials Research (NSF-DMR). The mission of DMR is to enable new discoveries in materials sciences and to address fundamental materials questions that may lead to novel technologies. DMR is also interested in preparing the next generation of materials researchers and development and support of instruments and facilities.

Durakiewicz, who received his PhD in experimental physics from University of Maria Curie-Sklodowska in 1998, joined the Laboratory in 1999 as a Director’s Funded Postdoctoral Fellow, and became staff member in 2003. He specializes in electronic structure of f-electron systems, angle resolved photoemission and ultrafast pump-probe photoemission, but has also worked on surface properties of metals, vacuum technology and stable isotopes in dinosaur teeth, meteorites, sedimentary rocks and speleothems. He has received 7 awards, gave 45 invited talks, published 134 peer-reviewed publications, 3 book chapters, 207 conference abstracts and reports, authored 7 patents. From 2010-2014, he was chairman of the User Advisory Committee of the Synchrotron Radiation Center (SRC), organizing 16 international conferences and workshops.

NSF supports the development of mathematical and physical sciences in several key areas including astronomy, chemistry, materials research, mathematical sciences, and physics, with a total FY 2012 budget exceeding \$1.3 billion.

Technical contact: Tomasz Durakiewicz

Celebrating service

Congratulations to the following MPA Division employees celebrating a service anniversary recently:

Christopher Romero, MPA-11 .... 15 years
Vivien Zapf, MPA-CMMS .... 10 years
Gautam Gupta, MPA-11 .... 5 years

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Materials Physics and Applications

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To submit news items or for more information, contact Karen Kippen, ADEPS Communications, at 505-606-1822 or kkippen@lanl.gov.

To read past issues see www.lanl.gov/orgs/mpa/materialsmatter.shtml.

Los Alamos
NATIONAL LABORATORY
EST. 1943

A farewell to David Morris

Members of MPA Division recently gathered to wish David Morris well as he departed his role as Director of the Center for Integrated Nanotechnologies to become Chemistry Division Leader.

Photos by Antonya Sanders, MPA-CINT

HeadsUP!

Posters, such as this one above, announce the program, being piloted this summer at Otowi and the NSSB.

LANL pilots new recycling guidelines at limited locations this summer

Los Alamos County has expanded items allowed in recycling blue roll carts and dumpsters for residents and businesses, and soon the Laboratory will follow suit. Look for stickers and posters announcing the Laboratory's changes at the Otowi Building and National Security Sciences Building (NSSB), where a two-month pilot program is underway.

With many more items allowed, such as plastics Nos. 1-7, the approach could make it easier to meet the Department of Energy's requirement that 50% of all nonhazardous waste at LANL be recycled.

Once in full swing, the Lab's new waste and recycling guidelines will match the County's. Meanwhile, until the Lab gives the go-ahead, hold off on changing recycling habits at other work sites.

If you are unsure what to do, please email wastenot@lanl.gov or ask your waste management coordinator for guidance. Placing nonrecyclable items in recycle bins can result in a lost recycle credit, and the material must then be disposed of as solid waste, at a cost of $60 per ton.